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OUTLINE ON CHAPT. 6

TRANSFORMERS.

I. THE TRANSFORMER.

A. General:
   1. Thepurpose of the traneformer is to convert electrical power from one current-voltage level to another current-voltage level.
   2. The transformer operates on the principle of electromagnetic induction.
   3. It consist of two coils placed so that the changing current in one induces an EMF in the other.
   4. The coil connected to the source of power is the primary coil, and the one connected to the load is the secondary.
   5. The only connection between the two coils is by flux linkage.
   6. The power consumed in the secondary is equal to the power in the primary.
   7. For maximum transfer of power all lines of flux set up by the primary must link the secondary coil.
   8. Some flux lines are allways lost so 100% flux linkage is impossible to achive.

B. Theory of operation:
   1. The ability to transfer power is a function of inductive coupling or mutual induction.
   2. The inductance in each winding should be as high as possible, since the greater the inductance, the greater the reactance will be, and the less the current needed to set up the flux linkage.
   3. The applied voltage in the primary is leading the current by 90 degrees, this current sets up a CEMF. which is 180 degrees out of phase with the applied voltage, and lagging the current by 90 degrees.
   4. The primary current sets up an induced voltage in the secondary, which is in the same direction that the CEMF in the primary. the current in the secondary is lagging the induced voltage by 90 degre.
   5. The secondary current sets up a CEMF wich is 18o degrees with the induced voltage, it also sets up flux lines opposed to the primary flux lines.
   6. Voltages across the transformer are 18o degrees out of phase and the currents are also 180 degrees out of phase lagging their respective voltages by 90 degrees.
   7. Under full load the transformr circuits act resistive with voltage and current in the secondery aproaching the in phase condition but still 180 degrees out with the primary.

C. Turns ratio:
   1. Voltage:
      a. The secondary voltage is directly proportional to the number of turns in the secondary compared to the number of turns in the primary. $\frac{Ep}{Np} = \frac{Es}{Ns}$ or $\frac{Ep}{Es} = \frac{Np}{Ns}$
      b. If the ratio Np/Ns is less than one the trasformer is step-down. If the ratio is more than one it is step-up.
      c. The volts per turn in any trans former are found by dividing the applied voltage by the turns in the primary.

2. Current:
   a. The power absorbed by the secondary is equal to the power delivered by the primary.
   b. The current in a transformer is inversely proportional to the number of turns $\frac{Ip}{Is} = \frac{Ns}{Np}$

D. Transformer losses:
  1. Efficiecy:
     a. 100% efficiency is impossible to reach due to losses of flux, hysteresiis, suturation, eddy currents and copper losses.
  2. Hysteresis losses:
     a. Hysteresis losses are due to the effect caused by the lagging of magnetization and demagnetization of the core.
     b. This type of loss can be minimized by using silicon steel for core
  3. Saturation:
     a. Saturation of the core causes losses because, once the corre is saturated with flux lines an incraese of current will not increase the magnetic fiald.
     b. Saturation losses are decreased considerably by using an air gap in the core.
  4..Eddy currents:
     a. Eddy currents are small short circuited currents induced in the magnetic cores which opose the flux lines.
     b. These currents are eliminated by using laminated cores.
  5. Copper losses:
     a. Copper losses is the name given to the power lost due to the D.C. resistance in the wire.

II. POWER TRANSFORMERS:
  A. Uses:
    1. The power transformer is used to convert the power output of a generator to high voltage-low current level for transmission and reconverts this power to a low voltage-high current level for consumption.
    2. High voltage transformers are filled with oil to prvent arcing between the windings.
    3. The power transformer used in electronic equipment are smaller units but their principle and duty is the same.
    4. Power transformers should allways be used withing 90% of it's rated load. If is opperated below, the reactance of the coils is increased setting up high induced voltages which may braek down the insulation.
    5. Commercial power transformers have a power factor of .9 and efficincy of 95%.
    6. The total amount of power consumed by a transformer with more than secondary winding is the sum of the power consumed by all the windings

  B. The autotransformer:
    1. The autotransformer is a special type, designed for low loss and good voltage regulation under varying loads.
    2. It is compossed of a single tapped winding, using part of the winding common to primary and secondary.
    3. As step-up all of the primary is part of the secondary.
    4. As step-down all of the secondary is part of the primary.
    5. The chief advantage is that the load may be varied without arcing, because the Ip and Is in the common part of the winding try to cancel each other out, since they are 180 degrees out of phase.

C. Turns ratio:

1. Impedance:
   a. The impedance of the secondary is the impedance of the load.
   b. The impedance of the primary is directly proportional to the square of the ratio of the turns in the primary to the turns in the secondary. $\frac{Zp}{Zs} = \frac{Np^2}{Ns^2}$

D. Impedance matching:

1. For maximum transfer of power, the impedance of the load must equal or match th impedance of the source.
2. The impedance can be matched by a transformer with the proper turns ratio.

E. Reflected impedance:

1. The impedance of the secondary is reflected to the primary.
2. If the load is pure resistive, the Es, Is phase angle is zero. The reflected impedance is like adding resistance in series with the primary windings.
3. If the load is inductive, the phase angle is not zero and the Is is lagging. This phase angle is reflected to the primary bet shifted 180 degrees, thereby affecting the primary circuit like adding capacitance in series.
4. Since adding capacitance in series is like adding inductance in paralell we can say that an inductive load is reflected to the primary acting like an inductance in paralell.
5. With a capacitive load we have the same conditions except that the phase angle is reversed, the Is leading.
6. Acapacitive load reflects a capacitor in paralell with the primary.
7. The reflected inductance is directly proportional to the square of the number of turns.
8. The reflected capacitance, is invresely propotional to the square of the number of turns.

III. Audio transformers:

A. General:

1. Audio transformers are designed to opperate anywhere in the audio fr.
2. The more expensive ones will have a flat response from about 30 to 15,000 cps.
3. To prevent to great a loss from hysteresis and eddy currents, audio transformers are wound in a small iron core with small size wire, but with many thousands of turns achieving inductances from 50 to 100 henrys.
4. At low fr. the reactance of the primary is less, therefore less current is flowing, and the low fr. show lower voltage gain.
5. At high fr. the distributed capacitance in the windings can be very high, specially the reflected capacitance, effectibly shorting out the high fr.

B. Microphone transformer:

1. Microphone transformers are used to match the low impedance of a microphone to the high impedance (input) of a vacuum tube.

C. Interstage transformer:

1. Used for coupling in high voltage gain amplifiers.
2. And to match the output impedance of a tube to the input impedance of another tube.

E. Output transformer:

1. Used to match the output impedance of a power amplifier to the load.

IV. Radio fr. transformers:

- A. General.
    1. At high radio fr. the losses in an iron core are too great, so radio fr. transformers are low inductance, air core.
    2. The air core brings the degree of coupling to about .65.
    3. The turns ratio in r.f. transformers have no significance.
    4. The reactance is very high due to the high rate of change of current.
    5. R.f. transformers are loose couple, and the inductances are determined by the fr. to which the circuit is going to be tuned to.
    6. The primary is used to match the output impedance of the tube.

- B. I.F. transformers:
    1. I.F. transformers have both windings tuned. The primary being part of a paralell resonant circuit, and the secondary being part of a series resonant circuit.
    2. The I.F. transformer is loosely couple, the amount determined by the bad-pass of the cicuit.
    3. There are three kinds of coupling: Loose, optimum and over coupling.
    4. I.F. transformers using tunable coils use powdered iron as the core, which is moved in and out of the coil to tune.
    5. The powdered iron is mixed with a nonmagnetic binder to prevent eddy currents.
    6. I.F. transformers are inside metal cans which act as shields to prevent the magnetic field from affecting nearby circuts.

- C. R.F. power transformers:
    1. They are used mainly for antena coupling in transmitters.
    2. Maximum power transfer is obtain by tuning both windings to resonance which in turn balance the reactances.

- D. Impedance matching at R.F.
    1. At R.F. turns ratio have no significance, since the coeficient of coupling is small.
    2. Impedance matching for maximum power transfer is obtain by tuning the primary (which is a paralell circuit) at resonance. Therefore offering high impedance to the output of the tube. And by tuning the secondary (which is a series circuit) to resonance, high impedance across the capacitor is obtain, which matches the high imput impedance to the next tube.